CHAPTER 2
MOUTH OF THE COLUMBIA RIVER NAVIGATION ANALYSIS

2.1 Introduction

This analysis of navigation at the mouth of the Columbia River (MCR) was made to determine the compatibility of the existing 55-ft entrance channel with the proposed 43-ft river channel. Specific issues are whether MCR would have to be deepened to handle the 43-ft draft ships expected in the proposed river channel and to estimate potential delays those ships might experience, at MCR.

2.2 Background

The navigation channel at the mouth of the Columbia River (MCR) is a tiered channel, with the north side being 55 ft deep by 2000 ft wide and the south side being 48 ft deep and 640 ft wide. The55 ft depth was intended to optimize the operations of the 40-ft Columbia River navigation channel. Improvement of the MCR is not part of the current channel deepening study. Therefore, it is necessary to determine if deeper draft ships might experience delays due to depth limitations at the MCR.

The Interim Feasibility Study and Final Environmental Impact Statement for the 55 ft MCR channel were-completed in March 1983. The project design was based on the results of the "Columbia River Entrance Channel Deep-Draft Vessel Motion Study" (VMS) completed by Tetra Tech, in September 1980. The VMS measured heave, roll, and pitch, to determine the vertical excursions of 53 ships, over a two-year period. A correlation was developed between wave height and vessel excursion that accounted for varying wave and vessel characteristics.

2.3 MCR Design

The MCR design criteria was for a 36-ft fresh-water (FW) draft vessel to be able to transit MCR 95o/0 of the time during "safe" wave conditions without exceeding the design excursion. Safe wave conditions were defined as waves less than 10 ft high, a condition that occurred 95% of the time according to the wave forecast used in the design. The design excursion was then defined as the value for which 95% of the excursions during 95% of the transits would not be exceeded. The resulting design conditions were as follows:

FW Draft (ft)	Design Excursion (ft)	MCR Depth (ft)	Min. Tide Stage (ft)	Max. Wave Height (ft)
36	16.5	55	0	8 (est.)
40	16.8	55	4	8 (est.)

As a comparison, on 7 of the 53 VMS transits the wave heights exceeded 10 ft and maximum downward excursion exceeded 20 ft on 6 VMS transits.

Given the above MCR conditions, a 55-ft deep MCR would be open to 36-ft FW draft ships 89% of the time and to 40-ft FW draft ships 44% of the time, based on combining the wave height and tide stage frequency curves used in the design report. Stated another way, the bar could be expected to be closed for 960 and 4900 hours each year for 36- and 40-ft drafts respectively.

2.4 Bar Pilots Operating Practices

As standard operating practices, the Columbia River Bar Pilots have two factors related to physical conditions in the river and entrance that limit transits on the MCR, The primary limitation is the underkeel clearance in the river channel between RM's 6 and 13. This restricts the draft and departure time of some deep-draft ships. The second limitation is the wave conditions at MCR, which can close the bar and prevent a ship from departing.

2.4.1 Underkeel Clearance Requirements

The minimum underkeel clearance in the river channel downstream of Astoria is normally the controlling factor for draft and time of departure. The standard operating practices for minimum underkeel clearance are; 4 ft on a falling tide, and 3 ft on a rising tide at Astoria. These are safety clearances and do not include allowances for squat. Squat is kept to a minimum by sailing at low speeds. The safety clearances are the same for both bulk and container ships. These, underkeel clearances do not correspond to a specific draft limitation because they are a combination of ship draft, controlling channel depth, and tide stage. Ships with 36-ft or less FW draft can meet the underkeel requirements essentially anytime, but about half the 40-ft FW draft ships must delay their upriver departures to wait for suitable tide stages.

The deeper draft ships time their departures from the upstream ports so their arrival at Astoria coincides with the required tide conditions. If a ship delays to wait for the tide, the ship must delay its departure from the upstream port, as there is no place to stop and anchor in the estuary. Only in an extreme case, such as a sudden storm, would a loaded ship be stopped and anchored in the estuary after departing an upstream berth.

2.4.2 Bar Closures

The standard practice for determining bar closures is for the individual pilot to decide if the wave conditions are unsafe either for the pilot boat or the ship scheduled to transit MCR. The bar is generally closed when there are breaking waves in the entrance. However, for less severe wave conditions the pilot must decide on the safety of a transit based on the characteristics of the ship and the waves.
The bar pilots do not differentiate based solely on a ship's draft when deciding on the safety of an MCR transit. A ship's ride and steerage characteristics are also important factors in deciding the

risk of a transit. The draft, length, beam, type and location of cargo, and hull design can all influence the ride and steerage of a ship.

Pilot experience has shown that ship length is an important factor in determining ship handling across MCR. Ships of around 600 ft in length experience large amounts of plunge because of the way they interact with the short wave lengths present at MCR. The longer, deeper-draft Panamax ships have significantly less plunge because their length dampens the wave effects. The reduced plunge offsets the deeper draft and results in less total penetration for the longer ships. However, rolling becomes more of a concern with the larger ships.

2.5 Regulatory Environment

The maximum draft on the Columbia River may be more a function of government regulation than physical parameters. The regulatory environment at the Oregon Board of Maritime Pilots tends to hold pilots at fault for any incident with a ship drawing over 40 ft, regardless of the circumstances. Given the potential risk of losing their license, bar and river pilots are hesitant to pilot ships over 40 ft draft available to do in the existing channel even if there were sufficient water depths so.

2.6 Observed MCR Operations

The available data on MCR transits was reviewed to determine historical practices. The total length of bar closures and transit drafts were reviewed for the time period 1961 to 1995. Also departure stage and tide condition data from 1991 through 1993 were examined. Data provided by the Bar Pilots showed the total length of time that MCR was closed each year declined steadily between 1961 and 1987, Figure 1. While over the same time period, the deepest drafts transiting MCR increased from 33-ft to 40-ft (FW draft).

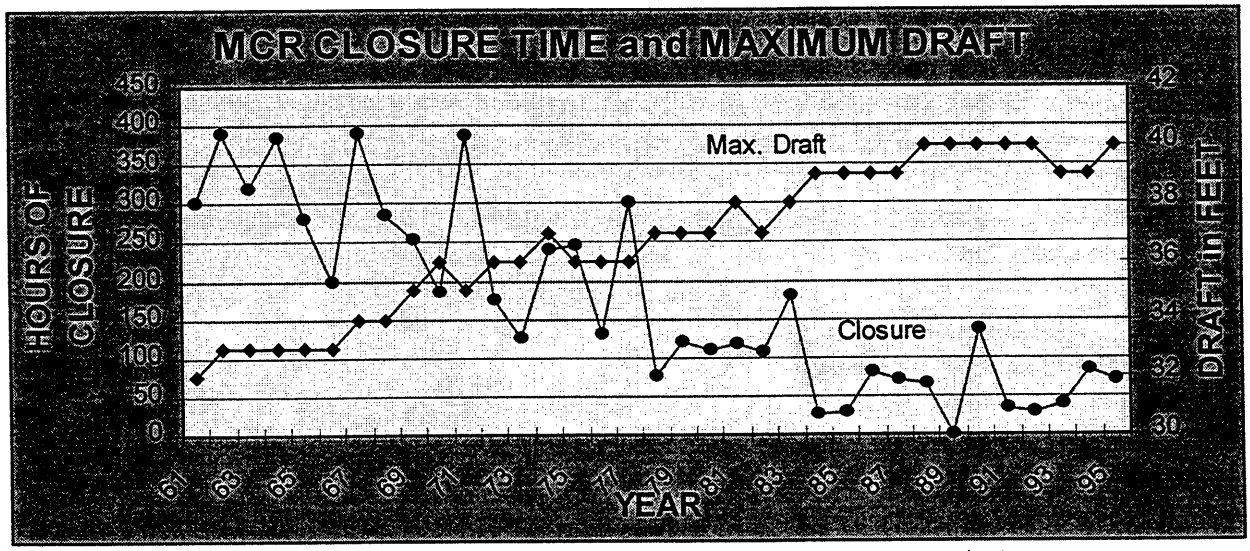

Figure 1. Hours of bar closure and maximum draft of ships transiting MCR each year since 1961.

In 1964, with a 35-ft river channel and 48-ft entrance, the 4-year average for bar closures was 350 hours per year and the deepest drafts were around 33 ft. In 1971, with a new 40-ft river channel and a 48-ft entrance, the bar was closed an average of 275 hours per year and drafts had increased to around 36 ft. By 1981, just prior to deepening the entrance, the bar closures had decreased to a 4-year average of only 105 hours per year and drafts increased to 38-ft. After deepening the entrance to 55-ft, bar closures fell to an average of near 50 hours per year and the deepest drafts increased to 40 ft.

There are clear trends of declining closure time and increasing drafts. However, the two trends may not be directly related to the depth of the MCR channel. New pilot boats received in 1967 and 1977 improved the pilot's ability to cross the bar in bad weather and contributed to a 70% decline in annual closure time between 1961 and 1981. This decline in closure time occurred without deepening the entrance channel and despite increasing ship drafts. Since 1984, the deeper MCR channel and longer ships were factors in reducing average annual closure time to only 50 hours.

The increases in draft seen at MCR resulted from numerous factors occurring both locally and globally. The global trend to deeper draft ships has been underway for many years and was facilitated locally by deepening the river channel in 1972 and the entrance in 1984. The establishment of the Peavy corn terminal in 1983 brought a fleet of larger ships that caused an increase in the number of ships drawing 40-ft or more. In recent years the increasing size of container ships has also contributed to the increase in 39- to 40-ft draft ships.

The development of the Loadmax stage forecasting system for the Columbia River in the mid-1980's allowed pilots to increase drafts by making better use of the available water depths in the river. It has also helped river pilots plan transits so they can meet the bar pilot's underkeel requirements. Of the 300 deepest draft ships that transited the Columbia River during 1991 through 1993, only about 10% did not meet the bar pilots' underkeel clearance guidelines.

Breaking waves, a hazard to both the pilot boats and commercial ships, are the most common reason for closing the bar. Breaking wave conditions are most severe during the few hours of strong ebb currents within a tidal cycle. However, during the last 10 years the average length of closure has been about 13 hours (1/2 a tide cycle) and the longest ranged from 20 to 36 hours. This suggests that closures are caused by a few large storms that generate high waves for extended periods of time.

2.7 Comparison of Actual vs. Design

There are several puzzling inconsistencies apparent when the 1983 MCR design parameters are compared to actual occurrences. These include the "safe" wave height and total length of closure, the assumed relationship between vessel draft and bar closure, and the expected excursion.

2.7.1 Wave Closures

The first inconsistency is under what wave heights ships will transit MCR. The design report assumed 10 ft as the maximum "safe" wave height that ships would transit, The design data indicated this would be exceeded 50/6 of the time or nearly 440 hours per year. Even during the 10 years before the MCR deepening the bar was generally closed only 100 to 150 hours per year, with a maximum of 300 hours in 1977. Since the MCR deepening, closures have been between 25 and 140 hours per year, far less than might be expected given the "safe" wave height criteria. It seems obvious that ships can and do transit MCR during higher than 10 ft waves. This was even documented in the VMS data that included transits with wave heights of up to 20 ft.

Another comparison of closure conditions was made by selecting two specific years, 1984 and 1992, to see how wave heights and closure times compared to the design assumption. Data from the Bar Pilots indicate that MCR was closed for 25 and 30 hours in 1984 and 1992 respectively, while wave heights exceeded 10 ft for 20% (1750 hours) and 10% (875 hours) of those years, respectively. The wave height/frequency data from 1984 and 1992 suggests that MCR is only closed when wave heights exceed 18-19 ft, which is more consistent with the VMS wave data and the recent annual closure durations.

2.7.2 Draft vs. Closure

The second inconsistency has to do with the bar being closed to some ships but not to others, The 1983 MCR design report predicted that for a given wave height, downward penetration would increase with increasing draft. Therefore, under certain wave conditions, ships with 36-ft draft could cross the bar when 40-ft draft ships would have to wait for higher tide stages to cross. However, experience has shown that the bar is open or closed on a ship by ship bases, with draft being only one of several determining factors.

While the deeper draft ships do frequently transit MCR during high tide, it is because of the underkeel clearance requirements within the river channel and not because of MCR wave conditions. The Bar Pilots' experience with deeper draft ships crossing MCR has shown that they handle better and have less excursion than the shallower draft ships. This runs counter to the findings of the VMS that showed slightly more excursion for the deeper ships. The variance is probably due to the similarity in length of the deeper and shallower draft ships in the VMS, and the greater length of the 40-ft draft ships currently calling on the river.

2.7.3 Excursion

The third inconsistency has to do with how much excursion a ship might experience. A wave height of about 8 ft with an excursion of 16.5 ft was used as the design values for the 55 ft entrance depth. During the VMS, measured excursions exceeded the design excursion by over 4

ft for similar wave conditions. There were also transits that occurred under much higher wave conditions that had excursions up to 9 ft deeper than the design value.

Since both excursion and wave height could exceed the design values, the risk of ships hitting bottom at MCR appears to be much higher than anticipated. Despite the apparent higher risk, there have been no reports of problems with ships hitting bottom at MCR. This suggests that there is less excursion, deeper water, or both at MCR than expected during the design.

The smaller than expected excursion experienced by the long, 40-ft draft ships could account for some of the lack of grounding, but does not explain why shallower ships are not hitting bottom. Changes in hull design and wider beams may have resulted in a reduction in the excursion for some of the shallower draft ships. There is also some speculation that ships may not ground because they are hydraulically cushioned as they near the bottom.

The hydrographic surveys consistently show bottom elevations deeper than 55-ft over most of the entrance channel. Pilots can follow the deep-water channel and gain extra underkeel clearance. The channel reach most exposed to high waves is from RM -2 to RM 0. This reach typically has controlling depths of 58-60 ft, providing an extra 3 to 5 ft of clearance. Ships may also be penetrating a portion of the 2-ft underkeel clearance safety zone. Based on the design assumptions, an extra 3 ft of depth plus 2 ft of underkeel clearance would allow ships to transit under wave conditions just 3 ft higher than the design values.

It appears that for MCR to be open an average of over 99% of the time, downward excursions must be less than originally estimated. This conclusion applies to ships with 34-ft drafts as well as those with 40-ft drafts. This is a critical safety issue that needs to be more clearly defined.

2.8 With Project Operating Practices

The Bar Pilots expect the with project operating practices to be very similar to the current practices. Since the underkeel clearance in the channel is normally the limiting factor, the 43-ft channel should allow 43 ft draft ships to transit the Astoria reach during higher tide stages. The Bar Pilots are confident that MCR can handle 43 ft draft ships without significant delays. There is a likelihood that the Pilots will initially be cautious with the deeper drafts, resulting in some small increase in delays over those currently experienced by 40 ft draft ships, but this is not expected to last long or to be significant.

Based on the excursion analysis done for the MCR deepening, 40 ft FW draft ships should be delayed because of wave conditions nearly 10% of the time. However, the historic record does not support this level of closure. Until the discrepancy between the theoretical results of the design report and actual operations can be explained, the actual operations must be used as the guide on the level of closures that can be expected,

The institutional constraint on maximum draft in the Columbia River is related to the authorized channel depth. This constraint applies to the Bar Pilots because their pilotage includes a 10-mile reach of the river channel, approximately from CRM 3 to CRM 13. This reach would be

deepened as part of the proposed deepening project. It is assumed that deepening this reach to 43-ft would shift the regulatory environment at Oregon State Board of Maritime Pilots to allow a maximum draft of 43-ft at the MCR.

2.8.1 Delays

Given the conflicting information on excursions and bar closures, there is much uncertainty in future MCR operations with a 43-ft river channel. Bar closures appear to be determined by the presence of breaking waves that make the bar unsafe for the pilot boats and commercial ships. MCR closures have been insignificant during the last 10 years, averaging only about 50 hours per year. Since this trend is not directly related to ship drafts, it can be expected to continue after the completion of the 43-ft river channel.

The Bar Pilots are expected to continue their requirement for minimum underkeel clearance downstream of Astoria of 4 ft on a falling tide or 3 ft on a rising tide. This will result in delays for 41- to 43-ft FW draft ships similar to those now experienced by 38- to 40-ft FW draft ships. Those delays are listed on the following table.

Draft	Available Transit Time per Tide Cycle	Delay Time per Tide Cycle	Avg. Time per Delay	Probability of Delay	Avg. Delay per Ship
43 ft	13.6 hrs	11.2 hrs	2.8 hrs	45%	1.3 hrs
42 ft	16.4 hrs	8.4 hrs	2.1 hrs	34%	0.7 hrs
41 ft	20.0 hrs	4.8 hrs	1.2 hrs	19%	0.2 hrs

2.8.2 Recommended Analysis

Since the MCR is expected to continue to be closed on a ship by ship basis, there is a need to refine the wave height, expected excursion and the level of risk of hitting bottom for wave conditions just below the breaking wave level. Given the potential consequences of hitting bottom, it seems like the design should be based on E95 or higher, of the extreme excursion values. The 1983 design failure rate of 5% leaves the potential for some ships to hit bottom up to 10 times during a single transit. The expected and actual excursions both need to be reviewed before the channel design is finalized.